

REMARKS

Review and reconsideration on the merits are requested.

Key Aspects of the Present Invention

The present invention is characterized by significantly refining (i.e., making fine) oxide inclusions or nitride inclusions remaining in a steel, preferably a maraging steel or a tool steel, and most preferably a maraging steel. Hereafter, for brevity, Applicants often discuss the present invention in the context of a maraging steel.

In order to refine the inclusions in the maraging steel when producing it, (1) a first melting process under vacuum (i.e., a primary melting process under vacuum), and (2) a second melting process under vacuum (i.e., a remelting process under vacuum) using a consumable electrode are carried out.

In the first melting process, Mg is added into the molten steel to make oxides admixed in the molten steel so as to provide a particular chemical composition a primary component of which is MgO. This process is referred to as an Mg oxide forming process. After melting, the consumable electrode is produced by casting.

The consumable electrode is melted (i.e., remelted) under a higher vacuum degree than that in the Mg oxide forming process. In the remelting process, the Mg oxide in the molten steel is dissociated to Mg and oxygen, causing the Mg content in the molten steel to be not more than 50% of that in the Mg oxide forming process.

Thus, in accordance with the present invention, oxides already included in molten steel are first changed to another type of oxides a primary component of which is MgO by adding Mg into the melt. Thereafter, the consumable electrode is prepared by casting while intentionally retaining the oxides (i.e., inclusions), a primary component of which is MgO, in the steel.

Second, in the remelting process (i.e., the dissociation process), the Mg oxide is dissociated to Mg and oxygen to remove unnecessary Mg by vaporization, thereby making the inclusions in the steel fine.

Thus, according to the present invention, the inclusions in the steel can be made fine simply by conducting a two step processes which includes the Mg oxide forming process and the dissociation process. This is a unique method which can be distinguished from a conventional method of refining intermetallic inclusions in steel by removing inclusion forming elements and gaseous components from molten steel as much as possible. In contrast, in accordance with the present invention, taking into consideration that it is impossible to completely remove nonmetallic inclusions from steel in an actual steel melting process, the presence of nonmetallic inclusions in steel is permitted but the inclusions are made fine to the extent practically possible.

The product of the present invention finds particular application in power transmission belts for automobiles which have a thickness of not more than 0.5 mm, which are made of maraging steel. Since the thickness is small, there is the problem of deterioration in fatigue strength due to the propagation of cracks initiated from nonmetallic inclusions. Thus, a new inclusion-refining technology is required in producing maraging steel for the thin power transmission belts.

According to the present invention, it is possible to make nonmetallic inclusions significantly fine down to not more than 16 μm of oxide inclusions and not more than 10 μm of nitride inclusions, as can be seen from the embodiments of the present invention, thereby providing a maraging steel suitably used for applications in which there will arise the problem of deterioration in fatigue strength. The thus obtained maraging steel has an excellent fatigue rupture property which is of an average rupture life of not less than 10^8 times.

DETAILED ACTION

Applicants appreciate the Examiner acknowledging receipt of the priority document (there is one priority document).

SPECIFICATION

A new Abstract is provided.

The Prior Art

JP 05-186813, abstract and machine translation (JP '813); US 3,764,297 Coad et al. (US '297); US 4,871,511 Smith, Jr. et al. (US '511); US 5,133,812 Kelly et al. (US '812); US 6,585,799 Zeze et al. (US '799).

Applicants now address the art rejections.

Rejection of Claim 1 as Anticipated by JP '813

JP '813 discloses a technique of deoxidation, denitrification and decarbonization of steel using Mg, which is different in principle from the present invention.

JP '813, states: "With regard to a method of producing a high purity steel without generating alumina type inclusions, deoxidizers were examined in place of aluminum deoxidation. (column [0003])". From this disclosure in JP '813, Applicants believe it clear that in accordance with JP '813 Mg does not change any oxides present in the molten steel into magnesium oxides, but, rather, in accordance with JP '813 oxygen is reduced in the molten steel using Mg.

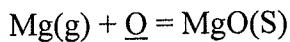
Further, in JP '813, no remelting process is carried out in contrast to the present invention where a remelting process is carried out using a consumable electrode. A principle of the invention of JP '813 is not to permit MgO (magnesia) to remain in an ingot obtained by one step melting process. Note the explanation in JP '813 that "Magnesia does not remain as nonmetallic inclusions in steel after the treatment under reduced pressure whereby a clean steel was

obtained." Namely, the "clean steel" in JP '813 is a steel free or substantially free of, MgO inclusion, which steel contains small amounts of gaseous components such as O, N, C etc., which is quite different from the present maraging steel with fine nonmetallic inclusions.

In contrast to the teaching of JP '813, in accordance with, in the present invention, MgO inclusions are caused to intentionally remain, as an oxide (a primary component of which is MgO) in the ingot after the first step melting process for the purpose of making nitride inclusions fine. Thereafter, upon subsequent remelting, the oxide containing as a primary component MgO is dissociated into oxygen and Mg gas, thereby making oxide inclusions fine in a solidified ingot. Thus, the present inventions results are different from the technique disclosed in JP '813 in the point of technical effect.

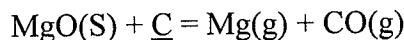
Reaction of the additive Ma in molten steel

(a) JP '813: There is shown the following equation.



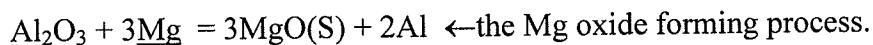
This equation means that deoxidation is intended in the technique of JP '813.

In a subsequent process, the following reaction is conducted.



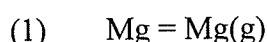
(b) Present Invention:

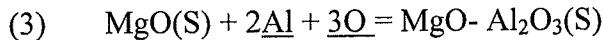
When beginning the first step of the Mg oxide forming process, oxides (e.g., Al₂O₃, etc) already exist in the molten steel. In the case of Al₂O₃, it reacts with Mg as follows.



This is an oxide reduction reaction in contrast to the deoxidation reaction of JP '813.

In the second step in accordance with the present invention, Applicants believe that the following reactions occur:





Reaction (1) promotes reaction (2), thereby resulting in MgO-refining. Further, when Mg-vaporization progresses in reaction (2), fine MgO inclusions combine with "Al" and "O" to form fine spinel oxide ($MgO \cdot Al_2O_3$) inclusions. This is an inclusion-refining step in the present invention. This inclusion-refining technique contributes to the production of an ingot from which power transmission belts of automobiles having a thickness of not more than 0.5 mm are produced.

As will be apparent from the above, in JP '813, Mg is used only for the purpose of obtaining a low-carbon, low oxygen, low nitrogen steel. The present invention is thus seen to be quite distinct from the teaching of JP '813 from the viewpoint of the technical approach involved, the technical effects obtained and the purpose of utilizing additive Mg.

Withdrawal is requested.

Rejection of claims 2-5 under 35 U.S.C. § 103(a) as being unpatentable over JP '813 as applied to claim 1 further in view of Coad (U.S. '297)

Applicants now turn to U.S. '297.

US '297 discloses a vacuum refining furnace capable of continuous refining. The steel produced in US '297 is a low-carbon and low-nitrogen steel. In US '297, additive Mg is not used. US '297 is silent on adjustment of any Mg and Al amounts, and has nothing to do with inclusion-refinement.

It should be noted that even if the contents of gaseous components (such as C, O and N) are small, nonmetallic inclusions do not automatically become fine.

Gaseous components in molten steel combine with inclusion-forming elements to form nonmetallic inclusions. Thus, the smaller the amount of the gaseous components in a molten

steel, the more advantageous the steel is from a viewpoint of amounts of inclusions. However, smaller amounts of gaseous components do not always contribute to inclusion-refinement. Even if the total volume of nonmetallic inclusions in steel is decreased by making the amount of gaseous components small, inclusions may agglomerate and become coarse. Thus, it is not always possible to make inclusions fine by decreasing the amounts of gaseous components. In order to make nonmetallic inclusions fine, a particular procedure is required. The present invention provides such a particular procedure in order to make nonmetallic inclusions fine, so that the present invention is quite unique, and is not suggested by the combination of JP '813 and U.S. '297.

Withdrawal is requested.

Rejection of claims 6 and 7 under 35 U.S.C. § 103(a) as being unpatentable over JP '813 as applied to claim 1 further in view of Zeze (U.S. '799)

US '799 discloses a steel slab excellent in workability and a method of producing the same. The Examiner points out that US '799 teaches a relationship between Al and Mg. However, in US '799 Al and Mg are added to steel not in order to make nonmetallic inclusions fine but in order to make crystal grains of the steel fine. In US '799, oxides of Al and Mg are allowed to remain in steel. In direct contrast to U.S. '799, in accordance with the present invention, oxides containing a primary component of MgO are dissociated in the second step (the remelting process) thereby causing the oxides containing a primary component of MgO not to remain in steel as much as possible. Since US '799 is silent on such remelting, US '799 does not suggest the present invention.

Although the Examiner indicates that a combination of JP '813 and U.S. '799 would render claims 6 and 7 obvious, Applicants respectfully submit that there is no reason or motivation for one of ordinary skill in the art to combine these two references. This is because

JP '813 relates to a technique wherein MgO (magnesia) is treated so as to cause the same not to remain in an ingot produced by only a single melting process and U.S. '799 relates to a process wherein oxides of Al and Mg are caused to remain in the steel in order to make crystal grains fine.

The approaches in JP '813 and U.S. '719 are so diametrically opposed that there is no reason or motivation for one of ordinary skill in the art to combine these references.

Withdrawal is requested.

Rejections under 35 U.S.C. § 103(a) of claims 8, 9, 11 and 12 as unpatentable over JP '813 further in view of Smith (U.S. '511) and the rejection of claim 11 on the same basis as unpatentable over JP '813 further in view of Kelly (U.S. '812).

US '511 relates to a maraging steel, and US '812 relates to a corrosion-resistant cutting tool. US '511 mentions vacuum induction melting (VIM) and subsequent vacuum arc remelting (VAR), and give the chemical composition of the maraging steel as pointed out by the Examiner. As can be seen from the explanation of lines 6 to 19, on page 2 of the present specification, a two step process as mentioned in US '511 is not unique since high grade steels have often been produced using such two step processes in order to control the state of nonmetallic inclusions.

In direct contrast to such prior art as disclosed in U.S. '511, the present invention is unique in the point of providing inclusion-refining processes using Mg. With respect to the Mg oxide forming process and the oxide dissociating process of the present invention, U.S. '812 is also completely silent thereon.

Miscellaneous

The present specification at page 11, line 28 - page 12, line 3 discusses the primary component MgO and the amounts thereof.

Maraging steel and the use thereof in power transmission belts is disclosed in the present specification at page 17, line 27 - page 18, line 20. Note also the discussion on the presence of TiN. See also page 31, lines 13-15 regarding maraging steel strip thickness. Steel strip thickness is also discussed at page 33, line 25.

Table 2 at page 32 discusses alumina type inclusions as meaning spinel ($MgO-Al_2O_3$) and Al_2O_3 .

Table 3 at page 35 gives the amount of alumina type inclusions with a size of 10 μm or more, the maximum length (μm) of non-metallic oxide inclusions and the maximum length (μm) of non-metallic nitride inclusion.

The specification at page 37, line 20 - page 38, line 9 discusses fracture initiation points and average rupture life, giving 10^8 times or more as a typical value.

Withdrawal of all rejections and allowance is requested.

The USPTO is directed and authorized to charge all required fees, except for the Issue Fee and the Publication Fee, to Deposit Account No. 19-4880. Please also credit any overpayments to said Deposit Account.

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